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Abstract

This document presents the design of a pulsed slow positron beam to study porous silicon and polymer films. Slow positrons are produced with a conventional technique using a ^{22}Na source and a tungsten film moderator. The goal of the proposed design is to reach a pulse duration of 0.3 ns FWHM at the target. The scheme of the beam includes two choppers and two bunchers. The distinctive features of the proposed design lie in the high compression ratio of positron pulses from an initial duration of 120 ns to a final width of 0.3 ns and in the versatility of the operation mode, which offers the possibility of re-tuning the operation parameters in order to adjust the pulse width and the interval between pulses. A high compression ratio (400) is achieved thanks to

an optimization of the voltage pulse shapes applied to the buncher drift tubes. This pulse shape is generated by a two-channel arbitrary waveform generator followed by a wideband amplifier. This design eliminates nonlinear aberrations in the bunching process and allows a compression ratio limited only by the intrinsic energy spread of the initial positron beam. The design of the apparatus allows to tune the time interval between pulses from 220 ns to infinity allowing to measure positron annihilation lifetime spectra, e.g. from porous silicon.

1 Introduction

Positron Annihilation Lifetime Spectroscopy (PALS) is an efficient method for studies of material surface properties [1] - [4]. The technique uses positrons either emitted from a radioactive isotope or delivered by a positron beam with an energy variable in the range 1 - 50 keV [5]. The *major advantage* of the PALS beam technique lies in its ability to control positron implantation into the sample, which can be depth-profiled by varying the incident beam energy [1].
The main parameters of a pulsed slow positron beam are: the positron rate at the target, the pulse repetition rate and the signal to background ratio in the positron annihilation detector. The pulse width is generally expressed as its value at half maximum (FWHM). The efficiency of a pulsing technique can be estimated by the pulse compression factor which is the ratio of the initial over the final pulse duration. For PALS with a slow positron beam, the counting rate should be about 10^3/s or larger in order to measure a typical spectrum containing 10^6 events during an acceptable time. For PALS polymer film studies, the time resolution should be around 0.3 ns (width of e^+ pulse less than 0.3 ns) and the interval between pulses about 50 ns. Studies of porous silicon, however, require a similar time resolution, but the time interval between pulses should be up to 1000 ns due to the relatively large fraction of ortho-positronium decays with a lifetime in vacuum of 142 ns.
Several experimental groups throughout the world have developed pulsed low-energy positron apparatuses of different designs, which differ by the methods of the positron production and the performance of the pulsed positron beam.
The Munich group [6] developed a pulsed positron system having a 150 ps (FWHM) duration pulse with a total time resolution (pulsing plus detector) of 250 ps, a repetition rate of 50 MHz, a counting rate of 4000/s and a peak signal to background ratio of 3000:1. In this apparatus positrons are produced from a 30 mCi ^{22}Na radioactive source and a moderator consisting of a 1 μm thick single crystal tungsten foil. A scheme including two RF bunchers and one RF chopper allows to form pulses with 150 ps FWHM duration from a DC positron beam with an efficiency of 65% (corresponding to 13 ns initial positron pulse width). A sawtooth voltage of 6 V_{pp} is used in the pre-buncher to produce 2 ns pulses from the DC beam. Then, a 50 MHz chopper cuts unbunched positrons in order to increase the signal to background ratio in the detector. Finally, a 50 MHz RF main buncher produces a longitudinal compression of pulses from 2 ns to 150 ps FWHM. The apparatus has an excellent time resolution, however, the 20 ns time window is too short for measurements of PALS spectra from materials such as porous silicon.
A slow positron pulsed beam with positron generation from an electron linac was constructed at the Electrotechnical Laboratory in Japan in cooperation with several laboratories [7]. At this facility the 70 MeV electron beam obtained from the low-energy part of a 500 MeV linac hits a tantalum converter and generates positrons. A tungsten moderator is used to obtain positrons with an energy below 10 eV. The slow

positron beam is stored in a linear storage section to generate a quasi-continuous beam. The pulsing system consists of a three-grid chopper, a sub-harmonic pre-buncher and a main 150 MHz buncher. The chopper generates pulses with an initial pulse length of 5 ns which are compressed with the two bunchers to 150 ps pulses. Positrons are then accelerated to an energy in the range 0.2 - 30 keV. The pulse period can be changed from 25 ns to 10 ms. A counting rate larger than 10^3/s is used for measurements of PALS spectra. The peak signal to background ratio of the apparatus is more than 10^4. The apparatus has a very good time resolution and a large counting rate due to the high intensity of the positron beam generated by the electron linac in spite of the use of very short initial positron pulses of 5 ns duration.
A pulsed slow positron beam system with a time-varying moderator bias voltage has been developed in Japan by a collaboration of several laboratories [8]. Positrons were produced by a 25 mCi ^{22}Na source and a tungsten single-crystal moderator of 6 μm thickness. The moderator foil was biased by a time-varying voltage from an arbitrary waveform generator and a post-amplifier, acting as pre-buncher. The pulse repetition rate of the pre-buncher was 25 MHz. The pulsing system includes also a three-grid chopper and a main RF buncher operating at a frequency of 75 MHz. A time resolution of 0.54 ns FWHM has been achieved and a pulsing efficiency of 50% with a time interval between pulses of 40 ns.
A similar pulsing technique has been used by the Osaka group [9], where a slow positron beam was obtained using an electron linac. The pulsing apparatus consists of a three-grid chopper and a gap buncher fed by an arbitrary waveform generator and a post-amplifier. A time resolution of 0.37 ns, a counting rate of 900/s with a time interval between pulses of 64 ns, and an initial positron pulse duration 5-15 ns were achieved. A peak signal to background ratio of about 100 was observed. The relatively large background was attributed to positron annihilation on four grids of the pulsing system.
A slow positron beam buncher based on a cavity with a new ferromagnetic material (FINEMET) has been developed to generate higher intensity e^+-beams by collecting positrons over a wider time span for measurements of the o-Ps lifetime [10]. The authors of the paper [10] report that they were able to collect positrons over a time span of 50 ns and obtained a final pulse width of 2.2 ns FWHM. The time interval between pulses was 1 μs and the beam intensity was 2.7 10^3 e^+/s.
In the present report we propose a design (section 2) of a pulsed slow positron beam apparatus based on positron generation by a radioactive source and a tungsten film moderator. The pulsing system consists of two choppers and two bunchers, which compress the positron pulses with an initial duration of 120 ns to a final 0.3 ns width. The large compression factor is obtained thanks to voltage pulses of optimum shape to eliminate aberrations in the bunching process in such a way, that the compression is only limited by the energy spread of the initial positron beam.

2 Description of the pulsed positron beam apparatus

2.1 Choice of the scheme for the beam

The design of a pulsed slow positron beam for studies of porous silicon and polymer films is determined first by the necessity of a relatively good time resolution of $\sim$ 0.3 ns and, secondly, by the large time interval between positron pulses of $\sim$ 1000 ns which is required. The existing facilities mentioned in the introduction have time resolutions up to 0.15 ns, but the initial positron pulse length is 5 - 15 ns. With such initial pulse lengths and time intervals between pulses of $\sim$ 1000 ns, as required for porous silicon and polymer studies, the efficiency of the use of the initial DC positron beam would be $\sim$ 1 % . In this case the counting rate will be two orders of magnitude less than in the DC mode of operation. With high intensity sources of slow positrons based on accelerators or nuclear reactors such an efficiency could be acceptable. With radioactive sources with an activity of $\sim$ 30 mCi, an efficiency of 1 % will lead to a very low counting rate of $10^1 - 10^2$/s. The present proposal for a pulsed slow positron beam contains a possible solution to increase the initial positron pulse length, keeping the time resolution at a value of $\sim$0.3 ns, hence, obtaining a higher efficiency.
For a given time resolution, the initial pulse duration is determined by the compression ratio of the pulsing apparatus. This ratio is limited by several factors; the main limitation comes from the conservation of the particle density in the phase space in accordance with Liouville's theorem. In the case of a one-dimensional particle motion this means that the time compression ratio is linked to the ratio of the longitudinal energy dispersions in the initial and the final positron beam bunches. The initial energy dispersion for a slow positron beam obtained by moderating the positrons from a radioactive source in a single crystalline tungsten foil was measured by several authors. Accordance to [11], it is $\sim$ 0.4 eV FWHM. Thus, a final energy spread of $\sim$200 eV makes possible, in principle, a time compression ratio of $\sim$500. This is approximately one order of magnitude larger than in present slow positron pulsed beam facilities.
However, in order to achieve such a high compression ratio it is necessary to eliminate aberrations in the bunching process. One source of aberration is connected to the shape of the time dependent voltage applied to the buncher gaps. It is well known, that in order to produce an aberration free particle velocity modulation with a buncher voltage, it is necessary to apply to the buncher gap a voltage which is a non-linear function of the time. For a one gap buncher followed by a drift space, the time dependence is given by the formula $V(t) = C/(T_o - t)^2$, where C and T_o are constants [12]. For a two-gap buncher the proper voltage dependence on time may be found by numerical calculations.
With an aberration free buncher the required compression of the positron pulse can be obtained by a single buncher or by using two or even several bunchers. However,

the one buncher scheme, though simpler, would require a high stability of the buncher voltage amplitude of $\sim 10^{-3}$ to obtain a compression ratio of ~500. The deviation from the calculated pulse shape and the stability of all voltages determining the positron energy in the system should be of the same order. Moreover, the resulting bunch, in a single buncher scheme, could contain tails connected to the initial energy spread and additional energy spreads from a chopper and from the beam transport due to the conversion of longitudinal to transversal momentum. For a sub-nanosecond positron beam bunch it would be difficult to design a chopper to cut these tails. A two buncher scheme is not so sensitive, and there are several designs of choppers operating satisfactorily under these conditions. Thus, a two buncher pulsing scheme with one or two choppers seems most suitable for the considered application.
The present design is based on tests done on a pulsed beam prototype. A compression ratio greater than 100 was obtained with electrons with one chopper and one buncher. The result is in good agreement with the calculations, supporting the hypothesis that two bunchers could produce a compression ratio of 400.

2.2 General description of the pulsed positron beam.

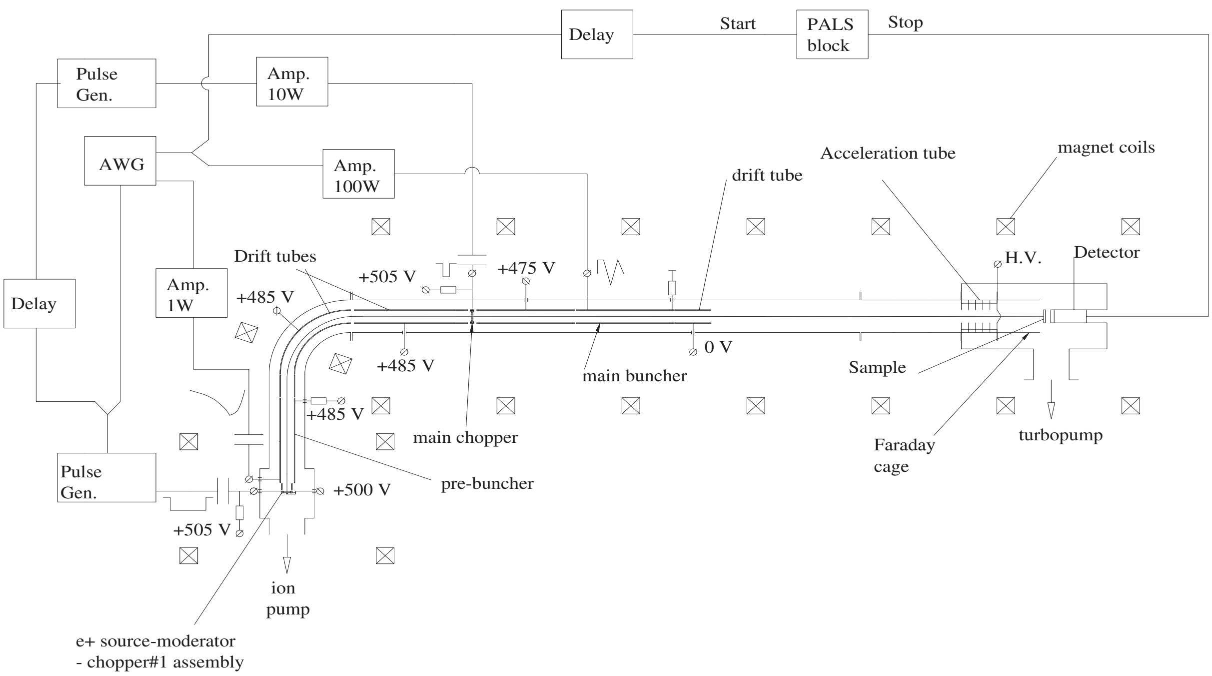

Figure 1: *Schematic diagram of the pulsed slow positron beam.*

The schematic diagram of the design of a pulsed positron beam is shown in Figure 1. Fast positrons are emitted by a radioactive source, such as ^{22}Na, with an activity of about 30 mCi. Slow positrons are produced in a tungsten moderator consisting of a single crystalline foil with a thickness of several micrometers. Positrons emitted from the moderator foil are guided to a sample by a magnetic transport system.

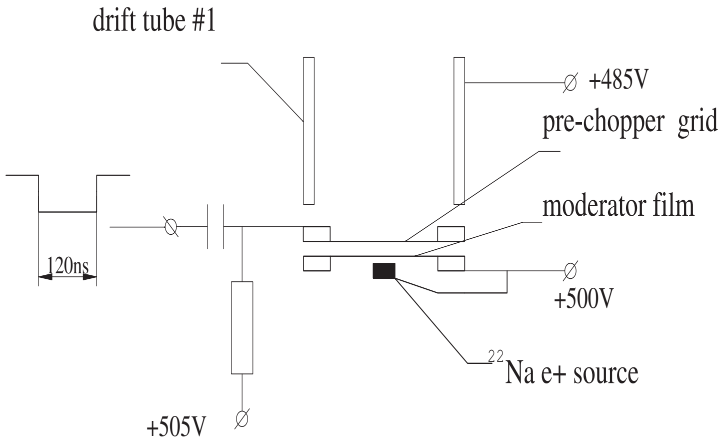

Figure 2: *Schematic diagram of the positron-source-moderator-chopper assembly.*

Positrons on their way to the sample pass through a pulsing system consisting of two choppers, two bunchers and drift tubes and are accelerated to an energy of 1-30 keV by an electric field in an acceleration tube. The sample is placed at high voltage and most parts of the apparatus, like the vacuum system, are at ground. A Faraday cage is used to transport accelerated positrons from the acceleration tube to the sample without deceleration. The size of this cage should be sufficiently large to reduce the background from the annihilation of positrons reflected from the sample [11]. Annihilation photons from the sample are detected by a detector consisting of a BaF_2 scintillator and a photomultiplier. The positron annihilation lifetime spectrum is recorded by measuring the time difference between the detector signal and the arbitrary waveform generator (AWG) signal supplied to the main buncher. The AWG signal can be used as a start and the detector signal as a stop signal.

2.3 The magnetic transport system

A magnetic transport system is the simplest way to transport a slow positron beam which has a relatively large energy spread. Inevitably the bunching process introduces some energy spread to the beam. An electrostatic transport system was also considered, but the main problem with an electrostatic transport is the large chromatic aberration due to the large energy spread in a pulsed positron beam which leads to a large beam size at the sample.
One problem of a positron beam transport system is the separation of slow and fast

positrons. There are several possibilities to build a positron velocity filter to select the slow, moderated component and reject the high energy positrons from the source. In the present design a simple bending filter, which is formed by a curved magnetic field, is considered. The radius of curvature for the central trajectory is 20 cm. In order to have adiabatic motion of slow positrons in this curved magnetic field, it is necessary to have a magnetic field strength of $\sim$100 G and an energy of positrons in this region of $\sim$ 20 eV. Compensation of the beam drift due to the curved magnetic field is planned to be made with magnetic field correctors.
The parameters of the magnetic system were calculated using the program 'TRACK'. The longitudinal magnetic field on the system axis adopted for the calculations was 100 G. The magnetic transport system consists of 10 coils; 9 of them have a 500 mm outer diameter. Each of them has 500 windings of 2 mm diameter wire. A DC power supply with a maximal voltage of 300 V delivers the current of 5 A through the coils. The distance between the centers of the coils is 350 mm. One coil (placed downstream of the moderator vacuum chamber) has an outer diameter of 250 mm and has 300 windings of 2 mm copper wire. The nominal Ampere-turns for this coil is 2000 A.

2.4 The positron pulsing system

2.4.1 The pre-chopper

The first chopper of the pulsing system (pre-chopper) produces positron pulses of 120 ns duration from a DC positron beam generated by the ^{22}Na source and the moderator foil, thus, eliminating positrons from the beam which could otherwise produce background. An assembly consisting of the ^{22}Na source, the moderator foil and the chopper grid is shown schematically in Figure 2. A potential of +500 V is applied to the moderator foil and to the positron source to ensure a proper energy of positrons in the drift area downstream from the buncher # 2, which is at ground potential.
The pre-chopper main part is a grid installed 1 mm downstream of the moderator foil. A voltage of 5 V applied to the grid relative to the moderator foil blocks the slow positrons emitted from the foil, which have a maximum energy of about 3 eV [11]. A potential of 505 V is applied to the chopper grid relative to the ground to have this 5 V potential difference between the grid and the moderator foil. This potential difference is decreased when a pulsed negative voltage, produced by a pulse generator, is applied to the chopper grid. It is applied to the chopper grid through a capacitor to keep the pulse generator at ground. When the potential difference between the chopper grid and the moderator foil decreases to a value smaller than 3 V, the positrons start to pass through the chopper grid. After the chopper they are accelerated by the voltage applied to the following drift tube relative to the chopper grid. When the voltage applied to the chopper grid increases back to 5 V, the positrons will be reflected again. In this way, using a voltage pulse of 120 ns duration and $\sim$ 4 V in amplitude,

it is possible to produce positron pulses from an initial DC beam. Note, that the rise time of the positron pulse produced by this chopper depends on the size of the gap between the moderator foil and the chopper grid. This gap should be as small as possible in order to decrease the rise time. For a reasonable gap value of 1 mm the rise time should be about 10 ns. The chopper induces an additional energy spread to the positron beam during the rise and fall times. The energy spread decreases when the amplitude of the chopper voltage decreases. The minimal pulse voltage amplitude which can be used in the chopper to have 100% transparency for positrons in the chopper 'open' state is equal to the full energy spread in a DC positron flux. If a chopper voltage pulse has smaller amplitude, the part of the positrons having smaller energy will be blocked and will not pass through the chopper. In this way it is possible to select an energy interval within the full energy spread, and to cut e.g. tails in the positron energy distribution.

2.4.2 The pre-buncher

The initial compression of the 120 ns positron pulses from the pre-chopper is performed in the pre-buncher. The pre-buncher is a two-gap non-resonant buncher. The gaps are formed by three drift tubes, two of them are at DC voltages and to the central one a nonlinear buncher voltage pulse is applied. Positrons passing the first gap with an initial energy of 15 eV receive a kick changing their velocity in such a way, that earlier positrons are decelerated by the gap voltage while late positrons are accelerated.
In the second gap the positron velocity is again modulated. The bunching of the positron pulse is continued in the following drift tubes and the shortest pulse duration is achieved at the second chopper position. The pre-buncher pulse voltage will be 5 V_{pp}. This gives an energy modulation of 10 eV downstream of the two-gap buncher, producing a time-compression factor of $\sim$25 in case of an initial longitudinal energy spread of 0.4 eV FWHM and with an aberration free bunching process. Thus, the expected width of the pre-bunched positron pulse is $\sim$5 ns FWHM.
Figure 3 shows the scheme of the pre-buncher. A potential of +485 V is applied to the drift tubes relative to ground. The buncher voltage pulse is produced by an arbitrary waveform generator (AWG) connected to a fast 1 W post-amplifier. This pulsed voltage is applied to the central drift tube of the buncher through a capacitor to have the amplifier at ground potential. The buncher drift tube diameter is chosen to form - together with the vacuum tube - a coaxial line with 50 Ohm impedance. A 50 Ohm resistor is connected to the central drift tube on the opposite side of the pulse voltage connection in order to achieve matching of the coaxial line. A DC potential of 485 V is applied to the central drift tube too in order to have an energy of the positrons of 15 eV in all drift tubes (without pulsed voltage).
The pulse shape for the two-gap buncher is determined by the calculations described in Section 2.6.

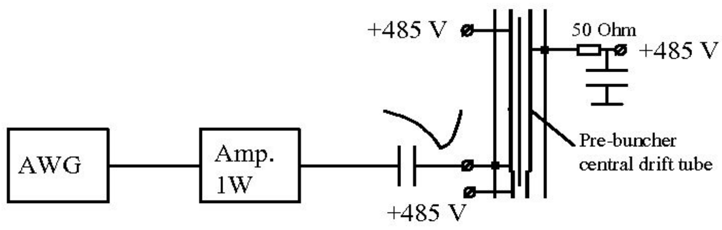

Figure 3: *Scheme of the pre-buncher.*

2.4.3 The main chopper

The second (main) chopper is designed to cut the tails in the bunches produced by the pre-buncher. It is important for the PALS technique to have positron pulses of symmetrical shape without tails, which otherwise would make the analysis of the PALS spectra difficult. A three-grid chopper described in [7] and used in several pulsed positron facilities is supposed to be used in the apparatus described here. The principle of operation of this type of chopper is similar to the operation of the pre-chopper described in this report. Three grids are used to have two neighboring gaps of small size and to achieve short rise and fall times for the chopped positron pulse. The distance between the grids should be $\sim$ 1 mm.

Figure 4 shows a scheme of the main chopper. A potential of +505 V (relative to ground) is applied to the central chopper grid to reflect all positrons when there is no pulsed voltage. A rectangular $\sim$7 ns wide pulse of 10 V is then applied from a pulse generator and a subsequent 10 W amplifier. This pulse is applied to the central grid of the chopper through a capacitor in order to have the amplifier at ground potential. A 50 Ohm load is used to match the connecting cable. A drift tube downstream the second chopper is at a potential of +475 V, and positrons have an average energy of 25 eV in the drift tube. The positron bunch length is increased from its value of 5 ns at the second chopper to 20 ns at the entrance to the main buncher drift tube. The positron energy is increased to 500 eV downstream of the drift tube by the voltage applied between the drift tube and the second buncher.

2.4.4 The main buncher

The second (main) buncher has two gaps, similar to the first one, but it introduces an energy modulation of 240 eV to the positron pulses, which leads to their compression to $\sim$0.3 ns FWHM. The main buncher is fed by a signal generated by the two-channel

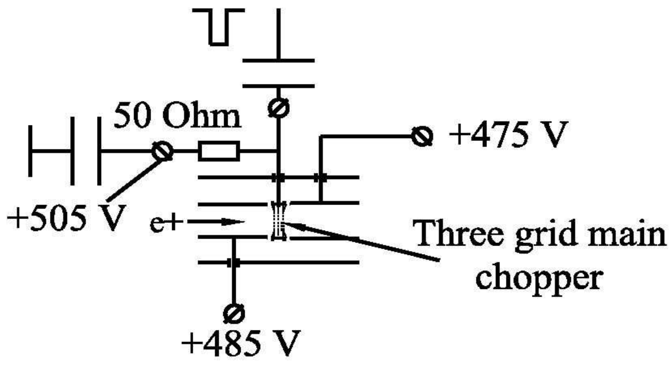

Figure 4: *Scheme of the main chopper.*

arbitrary waveform generator and a 100 W amplifier loaded by a 50 Ohm resistor. The buncher voltage pulse is 120 V_{pp}. The buncher drift tube forms a coaxial line with an impedance of 50 Ohm like the pre-buncher system (see Figure 1). The pulse shape for the main buncher is determined by calculations described in Section 2.6.

2.5 The vacuum system

The vacuum system of the pulsed slow positron beam should produce a clean vacuum of $\sim 10^{-8}$ mbar or better. The ultra-high vacuum is required because the performance of the positron moderator (tungsten foil) is sensitive to the surface contamination. The moderator efficiency and the energy dispersion of the positrons are affected by the moderator surface state. We plan to use a titanium ion pump and oil free turbo pumps and metal sealings in the vacuum system to reach the specified vacuum. In addition, we plan to anneal in-situ the moderator foil at 2000 °C with an electron beam from a separate electron gun.

2.6 Analytical design of the pulsing system

The simulations of the extraction optics, the beam transport and of the velocity modulation of positrons were performed with the GEANT4 [13] and 3D-Bfield [14] codes with the goal to minimize the timing resolution and optimize the shape of the bunching pulse.

The numerical solution for the shape of the pre-buncher and main buncher pulses are shown in Figure 5 and 6, respectively. They were calculated for the following

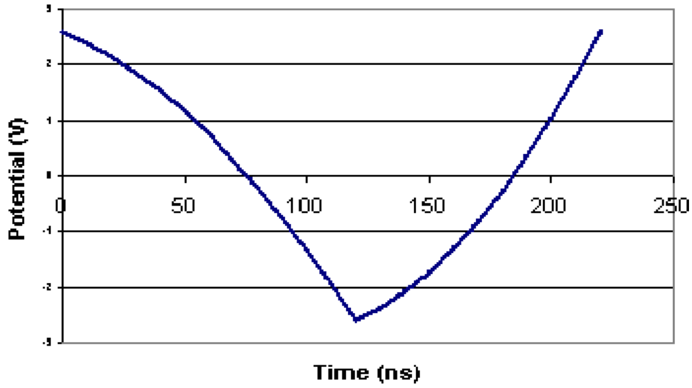

Figure 5: *The voltage pulse applied to the central drift tube of the pre-buncher.*

characteristics of the system:

- Moderated positrons have an average kinetic energy of $\simeq 3 \pm 0.5$ eV and are emitted isotropically from a flat film of 10 mm diameter. A low energy tail with a 10% intensity has been added to be consistent with measurements [11].
- The velocity filter tube axis is curved with a radius of 20 cm. Particles enter into the tube along Y (upward) and exit along the Z axis.
- The initial duration of the positron pulse formed by the pre-chopper is 120 ns.
- The initial duration of the positron pulse reaching the main buncher is 20 ns.
- The pre-buncher voltage pulse amplitude was chosen as 2.5 V in order to introduce an energy spread of 10 eV and to produce a time compression up to 25.
- The amplitude of the main buncher pulse should be within ± 60 V introducing an energy spread of 240 eV which should produce a time compression of 24.

The initial energy of positrons coming into the pre-buncher and into the main buncher were parameters of the calculation. An initial estimate gave energies of 15 eV and 500 eV, respectively.
The time dependence of the potential at the central electrode of the pre-buncher was calculated to minimize the positron pulse duration arriving at the main chopper. For the main buncher the corresponding potential shape was calculated to minimize the positron pulse duration arriving at the sample position. The voltage pulse shape is found as the result of an iteration procedure for the solution of the corresponding equations. Figures 5 and 6 show the resulting shape of the bunching potential

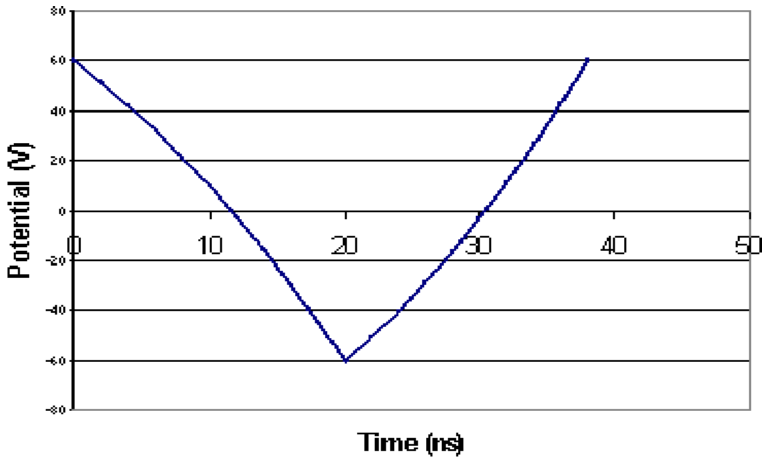

Figure 6: *The voltage applied to the central drift tube of the main buncher.*

pulses applied to the central drift tubes of the pre-buncher and the main buncher, respectively.

The buncher pulses can be approximated by a quadratic polynomial function of the time.

For the pre-buncher pulse we obtained (V_{pb} in volts and time t in ns):
for the time interval between [0 - 120 ns]: $V_{pb} = -2.053 \cdot 10^{-4} t^2 - 1.87 \cdot 10^{-2} t + 2.6$.
for the time interval between [120 - 220 ns]: $V_{pb} = 3.224 \cdot 10^{-4} t^2 - 5.8 \cdot 10^{-2} t - 0.2812$.

Similarly, for the main buncher we have:
for the time interval [0-20 ns]: $V_{mb} = -9.5 \cdot 10^{-2} t^2 - 4.1t + 6.0$.
for the time interval [20-37.9 ns]: $V_{mb} = 0.1224t^2 - 0.4054t - 101.01$.

The maximum efficiency of 54.5% is reached for a mode of operation with a time interval between positron pulses of 220 ns. A time-diagram of the pulses calculated for the pre-buncher and the main buncher in this mode is shown in Figure 7.

The time delay between the pre-buncher pulse and the main buncher pulse is 560 ns, it is determined by the time of flight of positrons between the pre-buncher and the main buncher entrance gaps.

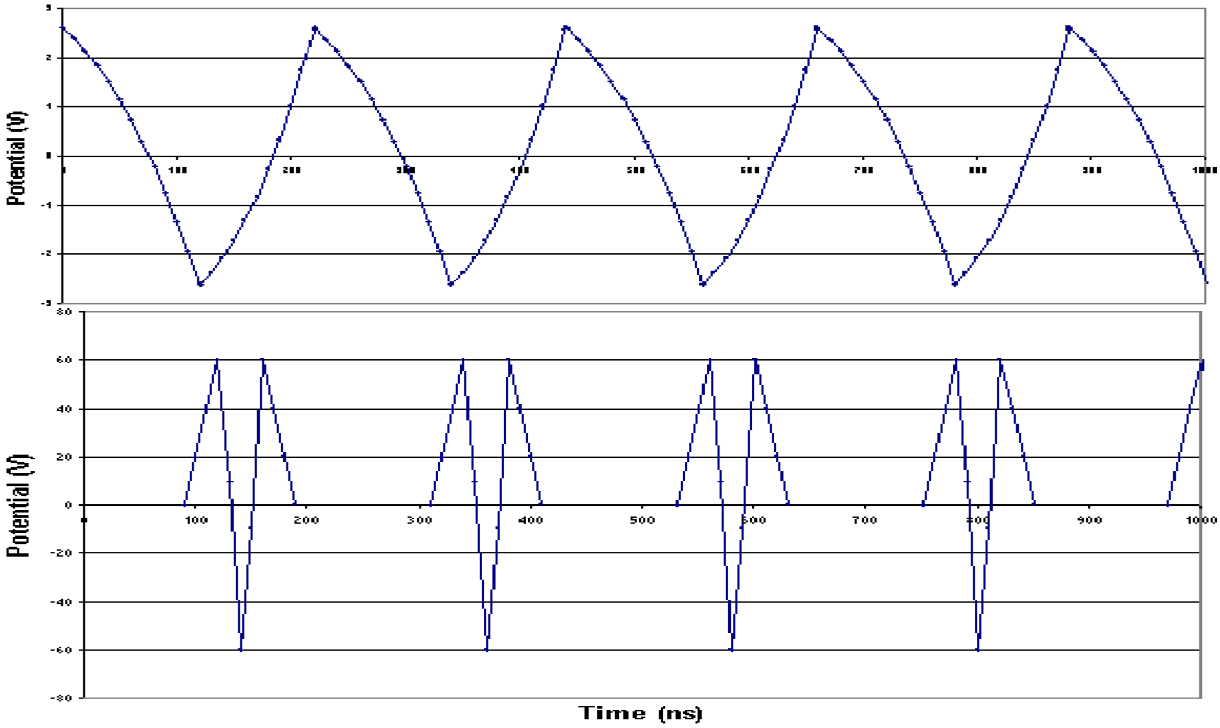

Figure 7: *Calculated voltage pulses to be applied to the pre-buncher (top) and main buncher (bottom) for a mode of operation with a time interval of 220 ns between pulses.*

3 Summary

The design of a high efficiency pulsed slow positron beam apparatus for studies of surface properties of polymers and porous silicon has been presented. The proposed pulsing scheme allows to compress a 120 ns initial positron pulse to a pulse with a duration of 0.3 ns FWHM. The interval between pulses can be varied from 220 ns up to infinity. The pulsing apparatus consists of two choppers and two bunchers. Such a high compression ratio (produced by the bunchers) can be achieved due to the elimination of aberrations connected to the shape of the potential pulse applied to the bunchers. It is planned to construct the pre-buncher and the main buncher as coaxial lines in order to eliminate pulse aberrations due to reflections of the corresponding electromagnetic waves feeding the buncher drift tubes. The time compression ratio of the apparatus is 400, which is a factor of 5 larger than in known pulsed slow positron beam facilities.
The present design is based on tests of a prototype pulsed beam, which is planned to be used for ortho-positronium lifetime measurements. A compression ratio of more than 100 was obtained with this pulsing apparatus, which included one chopper and one buncher. The result was in good agreement with calculations.
The distinctive feature of the present design is the possibility to change parameters of the apparatus, including the final positron pulse duration and the interval between pulses, which is important to adapt the apparatus to the PALS studies of different materials, such as polymer films and porous silicon.

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References

[1] Y.C. Jean, Material Sci. Forum **175-178** (1995) 59;
Positron Spectroscopy of Solids, edited by A. Dupasquier and A. P. Mills, Jr (IOS, Amsterdam, 1995) p.503.

[2] A.J. Hill, in: M.R. Tant et al. (eds.), *High temperature properties and applications of polymer materials*, ACS Symposium Series, **Vol 603** (1996).

[3] H.J. Ache, in D.M. Schrader, Y.C. Jean (eds.), *Positron and Positronium Chemistry*, Elsevier, Holland, 1988, p. 318.

[4] O.E. Mogensen, *Positron Annihilation in Chemistry*, Springer Series in Chem. Phys.V58, Springer, Berlin, (1995).

[5] P. Schultz and K. G. Lynn, Rev. Mod. Phys. **60**, 701 (1988).

[6] W. Baner-Kugelmann et. al., *Latest version of the Munich Pulsed Low Energy Positron System*, Material Science Forum, **529**, 363 (2001).

[7] R. Suzuki et al., *A positron lifetime spectroscopy apparatus for surface and near-surface positronium experiments*, Radiation Physics and Chemistry, **58**, 603 (2000).

[8] E. Hamada et. al., *New system for a pulsed slow positron beam using a radioisotope*, Radiation Physics and Chemistry, **58**, 771 (2000).

[9] M. Tashiro et. al., *Study of interfaces in polymer bilayers using a slow positron beam*, Applied Surface Science, **7898**, 1 (2002).

[10] H. Tijima et. al., *Time bunching of slow positrons for lifetime and time-of-flight measiurements of ortho-positronium*, Nuclear Instruments and Methods in Physics Research A, **483**, 641 (2002).

[11] P. Willutzki et. al., *An improved pulsed low-energy positron system*, Meas. Sci. Technol., **5**, 548 (1994).

[12] N. Oshima et al., *Design of a high-efficiency short-pulsed positron beam system*, Applied Surface Science, **116**, 82 (1997).

[13] The simulation programm is based on GEANT 3.21, CERN Program Library Long Writeup W5013.

[14] The program has been used to calculate magnetic fields for the Troitsk Electron Neutrino Mass experiment.